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Post-depositional alteration of humid tropical cave sediments: Micromorphological research in the Great Cave of Niah, Sarawak, Borneo

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A B S T R A C T

The post-depositional alteration of cave sediments is of critical importance for the recognition, identification and investigation of geoarchaeological and palaeoenvironmental evidence. There have been relatively few studies of tropical cave sediments using micromorphology and this work represents one of the most detailed with 26 samples taken from deposits in the West Mouth of the Great Cave of Niah that cover the last >~55,000 BP, and contain the earliest known evidence for the remains of modern humans in Southeast Asia. Cave sediments situated in the humid tropics are subject to relatively high temperatures and moisture conditions that promote high rates of chemical alteration and geomorphic change. This paper outlines those post-depositional features that occurred *in situ* in the West Mouth and include: translocation and concentration; bioturbation; excrement; bone alteration; plant alteration; clast alteration and guano decomposition. It examines their implications for recognising past human activities (e.g. fire-altered materials), the preservation of archaeological remains, the nature of palaeoenvironments and of localised physical and bio-geochemical processes.

1. Introduction

The post-depositional transformation of cave sediments affects interpretation of their depositional history and archaeological content. Disturbance may be so severe that original sedimentary features are distorted, archaeological materials are completely decomposed (e.g. Weiner et al., 1993), mixed (e.g. Hunt et al., 2015) and entire sequences may be removed through erosion (e.g. Stephens et al., 2013), mass movement (Dykes, 2007; Gilbertson et al., 2005), or by slumping prompted by bedrock dissolution (e.g. Glover, 1979). Investigating the processes of alteration can reveal valuable information on the diagenesis, and in turn the archaeological preservation and palaeoenvironments of such cave sites (e.g. Karkanas et al., 2000, 2002; Karkanas, 2001; Hedges, 2002; Weiner et al., 2002; Shahack-Gross et al., 2004; Cain, 2005).

In the humid tropics temperature and moisture levels are high and so rates of physico-chemical and geo-microbiological breakdown of cave deposits are generally increased. These processes are aided by a range of highly-adapted organisms (e.g. Chapman, 1980, 1982, 1984; Whitten et al., 1988; Gillieson, 1996) that inhabit these substrates with a result that interpretation of post-depositional alterations, taphonomy and geomorphic change can be particularly problematic (e.g. Gilbertson et al., 2005, 2013; Dykes, 2007; Hunt et al., 2015).

However, studies from the humid tropics of post-depositional alteration of archaeological sediments are scarce and with few exceptions (as mentioned) above are typically limited to sideline observations within broader geoarchaeological investigations (e.g. Wasson and Cochrane, 1979; Bull and Laverty, 1981; Laverty, 1982, 1983; Gillieson and Mountain, 1983; Gillieson, 1985; Datan, 1993). Micromorphology provides some of best insights into post-depositional alteration since it is possible to observe directly and in great detail the breakdown of sediments and the resultant transformation products at different stages of alteration (e.g.

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Delvigne, 1998; Stoops, 2003; Goldberg and Macphail, 2006) and is all the more powerful when supplemented with geochemical and mineralogical studies (e.g. Karkanas et al., 1999, 2000; Weiner et al., 2002; Goldberg and Sherwood, 2006; Goldberg et al., 2015).

Within the tropics, however, micromorphology has been applied to only a small number of cave and rockshelter sites including Leang Burung 2, Indonesia (Frank, 1981); Colless Creek, Queensland, northern Australia (Magee and Hughes, 1982); Nombe rockshelter, Papua New Guinea (Gillieson and Mountain, 1983); Hagop Bilo rockshelter in Madai Baturong, Sabah (Magee, 1988). McConnell and Magee (1993) also reviewed micromorphological studies at several sites in Australasia and Southeast Asia. An outline of many of these findings is provided in Stephens et al. (2005). More recent studies in tropical Asia include the investigation by Kourampas et al. (2009) and Perera et al. (2011) at rockshelters in Sri Lanka and that of Lewis (2007) and Mijares and Lewis (2009) at cave sites in the Philippines.

Stephens et al. (2005) analysed the micromorphology of four thin section samples from palaeosurfaces and cave infill sequences associated with human remains in the Great Cave of Niah, in the Malaysian State of Sarawak, Borneo (Fig. 1). The work presented here demonstrates evidence for post-depositional change and includes a much greater number of thin section samples from the site (n = 26), covering the main deposits in the West Mouth over the past ~50,000 BP and not just focussing on those associated with the ancient human remains.

The West Mouth of the Great Cave is important because it contains the oldest known remains of *Homo sapiens* in Southeast Asia, including the ‘Deep Skull’, and a vast archive of materials has been excavated and studied by Harrisson (1958, 1970), Majid (1982) and the Niah Cave Project of Barker et al. (2000, 2001, 2002a,b, 2003, 2004, 2007, 2013) which has greatly furthered understanding of human–environment interactions during the Late Quaternary in the humid tropics (e.g. Stephens et al., 2008; Hunt et al., 2007, 2012; Hunt and Gilbertson, 2014; Gilbertson et al., 2005, 2013; Lloyd-Smith et al., 2013; Barton et al., 2013; Rabbet et al., 2013; Reynolds et al., 2013). The extant surfaces and associated sediments associated with the Deep Skull were dated at ~40,000 BP in the West Mouth of the Great Cave of Niah. Recent geoarchaeological research indicates this skull dates to approximately ~35,000 BP and was placed at that time into a pit excavated into the underlying deposits (Hunt et al., 2012; Hunt and Barker, 2014). Unfortunately, all of the sediments and their sedimentary boundaries at and around this Skull were excavated without their recognition or appropriate record, apart from residual materials adhering to the skull that were investigated by Hunt in the Natural History Museum in London. The scale of the loss of potential information for geoarchaeological research that are consequent upon the excavation of vast amounts of material in the excavations of the 1960s and 1970s is illustrated and explained in Gilbertson et al. (2013).

This micromorphological investigation and the resulting detailed archaeological and geological histories set out below is based on a limited number of surviving exposures which are often small and fragmentary, and often not in the locations that would have provided good chances for elucidating the prehistory of this important cave. This study seeks to show the important features and processes of *in situ* post-depositional alteration rather than features produced by reworking, a process that is discussed further for the West Mouth by Dykes (2007), Gilbertson et al. (2013) and Hunt et al. (2015). It examines the effect of hot and humid environmental conditions on site deposits, stratigraphy and archaeological components including features such as: translocation and concentration; bioturbation; excrement; bone alteration; plant alteration; clast alteration and the decomposition of guano. Implications are also drawn for the significance of such features for recognising past human activity (e.g. fire-altered materials), the preservation of archaeological remains, detailed palaeoenvironmental reconstruction, and for elucidating the nature of localised physical and bio-geochemical processes.

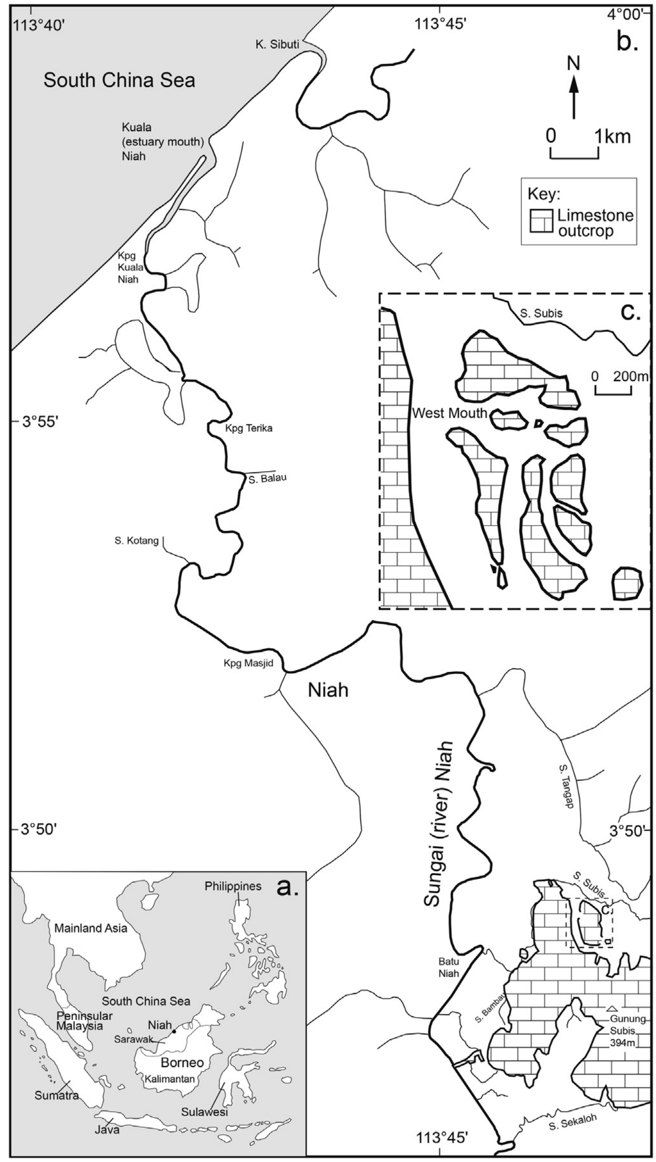

Fig. 1. a) Niah in the Southeast Asia context. b) Location of the Subis Limestone Massif within which the Great Cave of Niah occurs, in the Sungai (River) Niah basin and adjacent to the South China Sea. Position of village settlements (kampung - kpg) are also shown. c) Location of the West Mouth, Great Cave of Niah, within the Subis Limestone Massif. Adapted from Stephens (2005) and Stephens and Rose (2005).

1.1. Site geography, geoarchaeology and Late Quaternary stratigraphy

The West Mouth of the Great Cave of Niah is located at 3°49′09″N and 113°46′42″E in an isolated limestone hill within the Subis Limestone Massif, set in a sub-coastal sandstone plain of north–central Sarawak, north Borneo, ~10 km south from the coast of the adjacent South China Sea (Fig. 1a and b). The Great Cave of Niah has several entrances with the West Mouth being the largest, ~250 m wide and ~60 m high and is where the most ancient